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15.1 INTRODUCTION

This building block addresses several potential fish screen facilities that may be proposed as an integral part of future actions in the Sacramento–San Joaquin River Delta (Delta). New fish screen facilities, designed to meet current fish protection criteria, have been evaluated in various levels of detail over the years. The facilities described below would significantly influence how the Delta may be configured and operated to improve fish protection.

Figure 15-1 shows the flash card for Building Block 3.3: Install Fish Screens.

15.1.1 Background

A number of water withdrawals exist in the Delta. They water withdrawal rate at these facilities ranges from less than 1 cubic foot per second (cfs) at individual farm intakes to over 10,000 cfs at the State Water Project's (SWP's) Banks Pumping Plant in the south Delta. Less than 1 percent of the diversions in the Delta have fish screens that meet current fish screen criteria. The largest diversions at the state and federal pumping facilities in the south Delta offer some fish protection. but these facilities were not designed to provide the level of entrainment protection that new facilities offer.

Many studies have been conducted over the last several years to evaluate the types of screens that could be installed at the intakes in the Delta. These studies have evaluated the types of fish protection devices to employ at a "through-Delta" facility that would divert water from the Sacramento River and into the central Delta, at an "isolated facility" that would divert water from the Sacramento River into the south Delta pumping plants via a new canal around the Delta, at improved fish collection facilities at the south Delta pumps at the Banks and Tracy pumping plants; and at the multitude of agricultural diversions throughout the Delta.

Over the years, fish that use the waters of the Delta have been listed as endangered and threatened under both federal and state endangered species laws. Many of these listings have taken place since some of the first screening studies were performed. Also, the guidelines and criteria specified by the federal and state fisheries agencies have changed since the first of these studies were undertaken. For example, Delta smelt have been listed, and as a result, agencies have established a guideline that the approach velocity to screens should be 0.20 feet per second (fps) instead of the previous standard of 0.33 fps. This criterion has served to increase the size of the screen area by 65 percent.

15.1.2 Purpose and Scope

The purpose of this building block is to provide a conceptual overview of possible fish screens in the Delta and a general assessment of their function based on our current understanding of how they may be designed. Although new fish screens may reduce the risk of fish entrainment into diversions, many other factors can also influence fish survival and protection, including water quality, instream flows, and water operations. Also, some proposed fish screens rely more on the integrity of Delta levees and existing facilities than others. Fish screens should therefore be considered in the context of how they will add value to other actions that improve water supply reliability while improving fish protection.

The analysis of this building block is meant to provide a conceptual evaluation of the proposed fish screen facilities at new Sacramento River diversions (i.e., through-Delta facilities and isolated facilities), at the Tracy (federal) and Banks (state) pumping plant intakes, and at the many other diversions in the Delta. This analysis uses previous studies to obtain information on project alternatives. A likely facility concept was selected for each of these sites for evaluation purposes only. Costs were taken from the literature and escalated to present value. The assessment of risk was based on information from the literature and general knowledge of fish screen performance in the Delta.

15.1.3 Objective

The objective of the building block is to assess the costs and risks of the various screening options for the existing and proposed new intakes in the Delta.

15.2 CONCEPTUAL DEVELOPMENT OF IMPROVEMENT

15.2.1 Criteria and Basis of Design

For the purposes of this study, all fish screening criteria presently in effect for National Oceanic and Atmospheric Administration (NOAA) Fisheries and the California Department of Fish and Game (CDFG) are assumed to apply. These criteria designate the approach velocity to the screen and other design criteria. The minimum size of the screen is calculated by dividing the desired screened flow by the approach velocity. The amount of screen area effectively sets the size of the whole screening structure. In California, the approach velocity criteria is 0.33 fps; however, in the Delta, an approach velocity of 0.20 fps is specified for the protection of Delta smelt (and potentially other species as well). This criterion alone increases the screen area by 65 percent for facilities built in the Delta versus other areas.

Other criteria have an effect on the size, complexity, and cost of screening facilities. These criteria include the type and size of bypass pipe, the maximum interval for cleaning the entire screen, and the requirement for a flow velocity along the face of the screen. These criteria are applied to all types of screening facilities considered here.

The basis for the design of the facilities described for this building block is taken from reports documenting previous engineering and biological studies. After reviewing our previous experience with fish screening in the Delta and San Joaquin and Sacramento rivers, we have selected types of projects that meet the screening criteria and are most likely to provide effective fish screening.

15.2.2 Isolated Conveyance Intake

15.2.2.1 Previous Studies

Transferring relatively fresh Sacramento River water around the Delta has been discussed and studied for many years. A Delta conveyance facility was originally a feature of the Burns-Porter Act, which authorized construction of the SWP, and this facility was to be built after the initial facilities were constructed. In 1965, the Interagency Delta Commission recommended a Peripheral Canal. In 1969, the Department of the Interior adopted the U. S. Bureau of

Reclamation's (USBR's) Peripheral Canal Feasibility Study. In 1975, the California Department of Water Resources (DWR) began to reassess the Peripheral Canal and initiated several biological and engineering investigations for its implementation. Because of the controversy surrounding the proposed canal and its operation, the State of California put the project before the voters, and the plans were defeated. Although studies were put on indefinite hold, the state continues to explore other transfer options and diversion facilities, such as the New Hope Canal, which was similar to a "through-Delta" facility concept.

The California Bay-Delta Authority (CALFED) program revived planning activities for new conveyance facilities in the 1990s and early 2000s as part of a program to improve water supply reliability and the ecology of the Delta. These studies referred to a new conveyance facility as the "Isolated Delta Conveyance." The term Isolated Conveyance will be used in this section except in references to past reports that used the term Peripheral Canal.

Studies for providing fish screens for the Peripheral Canal were initiated early in the study process. In the early 1970s, due to low screening efficiencies of the louver systems used in the south Delta at the state and federal fish facilities, it was decided that the Peripheral Canal diversion would be screened using positive barrier screens to exclude fish from entering the canal. It was also decided that eggs and larvae would not be screened because of the lack of a technology for screening them in such a large flow. The CDFG, DWR, USBR, and U.S. Fish and Wildlife Service performed a series of studies and tests with different types of screens and cleaning devices at Hood on the Sacramento River for the Interagency Ecological Program (IEP). The results of these studies were reported in a series of technical reports. Technical Report No. 6 describes the findings of the Delta Fish Facilities Program through June 1982 (Odenweller and Brown 1982). The Peripheral Canal research studies on fish screens formed the basis for fish screening criteria and guidance in California.

In 1996, CALFED assembled a team of interagency fish facility experts and an outside advisory board to help evaluate several options being considered, including Isolated Conveyance facility concepts of various sizes. This CALFED Fish Facilities Technical Team specifically focused on developing fish screen feasibility for the Isolated Conveyance and improvements at the south Delta pumps (CALFED FFTT 1996). In June 1997, the CALFED Fish Facilities Technical Team made a series of observations and recommendations in a report (CALFED FFTT 1997). The more pertinent recommendations were the following:

- Flows of 15,000 cfs can be screened; however, the facility should be designed in modules of about 3,000 cfs each, because screens of this size have proven effectiveness.
- An Isolated Conveyance was recommended over intake and screening facilities at the pumps in the south Delta.
- The latest screening technology using positive barrier screens should be used.
- On-river screening concepts should be considered for screens of 5,000 cfs or less.
- Multiple bay vee-type screen configurations should be used for screens located off-river.

This report also described a number of alternatives for fish screening facilities for the Isolated Conveyance and the south Delta pumps.

Other studies of the Isolated Conveyance were performed under the CALFED program. The CALFED Storage and Conveyance Refinement Team investigated the costs of three sizes of

Isolated Conveyance: 5,000, 10,000, and 15,000 cfs (CALFED SCRT 1997). The intake was envisioned at or near Hood on the Sacramento River. It would consist of a trash deflector, a trash rack, floodgates at the river bank, a sedimentation basin, vertical-plate vee fish screens with baffles, and a bypass system with an inclined weir and control buildings. The cost of the fish screens and bypass only was estimated at $10,000 per cfs in October 1996. This estimate was increased for inflation to $13,000 per cfs for October 2005. The cost of the intake works was in addition to this amount.

Additional studies looked at various aspects of the Isolated Conveyance, including an incised canal to prevent seepage onto adjacent farmlands and potentially to reduce costs (CALFED 1999). Costs were computed for this alternative. The incised canal report assumed a 10,000 cfs diversion and the same intake and screen configuration as mentioned above.

In 2000, the CALFED Record of Decision outlined a preferred Stage 1 alternative, which included a screened through-Delta facility concept and improved fish facilities in the south Delta (CBDP 2000). The Record of Decision left open the possibility of an Isolated Conveyance if a through-Delta concept was not feasible. The screen facilities would be similar to those of an Isolated Conveyance, except that they were limited to 4,000 cfs capacity and would require upstream fish passage facilities because they would be open to the central Delta. In March 2007, the preliminary costs of a through-Delta concept facility were released (DWR 2007c). A value engineering study was conducted using the results of this report (DWR 2007b). Costs from these reports provide updates to the costs developed in previous and related studies.

15.2.2.2 Screen Structure Description

Different types of screening facilities for the intake to the Isolated Conveyance were reviewed by the CALFED Fish Facility Technical Team. The most favored option was a multiple-vee screen facility in the diversion canal off the river with a bypass back to the river. This vee screen alternative is selected as the screen that would be moved forward in future analysis of the Isolated Conveyance and is described in more detail below. It is assumed that the Isolated Conveyance is totally isolated and that no fish would be present in the conveyance and therefore no upstream fish passage facilities would be included in the screening structure or intake. Ancillary structures, which are directly attached or required by the fish screens to operate successfully, are included in the description and cost estimate. The individual features of the screening facilities described below apply to the three diversion sizes: 5,000, 10,000, and 15,000 cfs.

- Debris boom. A debris boom would be installed at the intake and would be aligned with the river bank upstream and downstream. It would be supported on floats and extend a few feet under water. Floating debris moving with the current in the Sacramento River would slide along the debris boom and not enter the canal.
- Trash rack. A trash rack would be installed at the upstream end of the fish screen structure. It would extend the width of the intake channel to the screens and be constructed of steel. The bars would be oriented at an angle of about 75 degrees from the bottom of the channel and would have a spacing of between 4 and 6 inches. Certain parts of the rack would have bar spacing of about 1 foot to allow passage of larger fish. The trash rack would have one or more automatic cleaners, such as the Bracket-Green rake, installed in 2005 at the Skinner Fish Facility upstream of the Banks Pumping Plant.

- Fish screens. The fish screen facility would consist of a series of vertical flat plate screens oriented in a vee configuration. Each vee module would consist of a rectangular channel with the vee screen inside. The channel would be about 65 feet wide and 500 feet long and the water would be about 20 feet deep and flow at about 2 fps. Each module would screen about 2,500 cfs. Water passing through the trash rack would enter the open end of the vee and pass through the screens along each side. The approach velocity to the screens would be about 0.2 fps, the velocity specified in fishery agency criteria for Delta smelt. This facility would require about 12,500 square feet of fish screen. The screens would require cleaning, which would be accomplished with a brush cleaning system that would move the brush along the screen to prevent debris from clogging the fish screens.
- Bypass. About 80 to 100 cfs would continue to the apex of the vee. This bypass flow would contain all the fish and would be transitioned to a channel or pipe for return to the river. The bypass would require a pump to gain sufficient head to return the bypass flow and fish to the river. In the past, pumped bypasses have not been allowed but recent studies at the Tracy and Banta-Carbona screening facilities have shown that certain pumps can safely pass fish in a bypass system.
- Other facilities. In addition to the main facilities discussed above, other ancillary facilities would be required, including a storage and control building. Because the screen cleaners and bypass pumps require computerized controls and monitoring systems, a building to house these and other electrical equipment would be needed. A means of evaluating the effectiveness of the screening system would most likely be required. This function would be housed in a small covered area on the bypass conveyance just downstream of the bypass pumps.

15.2.3 Banks Pumping Plant Intake

15.2.3.1 Previous Studies

The Banks Pumping Plant began operation in 1969, along with the J. E. Skinner Fish Facility (JESFF). These facilities are about 8 miles west of Tracy at the south end of the Delta and were designed for an ultimate pumping capacity of 10,300 cfs. The exiting facilities use louver screens (bar slats placed at an angle to the flow on 1-inch spacings), which behaviorally guide fish to several fish bypasses. Louvers are about 75 percent effective at preventing salmon fingerlings from being entrained through the louvers; however, the efficiencies for smaller fish and other Delta species are much lower or unknown. Because the Banks Pumping Plant is at a dead-end channel in the south Delta, all fish collected in the fish bypasses are captured in large holding tanks. About two to three times daily, these fish are trucked to the western Delta and released away from the influence of the pumping plant. Fish survival in the collection and transportation process is currently being investigated because some fish, such as Delta smelt, are not believed to survive this process well.

Clifton Court Forebay (CCF), a gated 2,200 acre shallow impoundment just upstream of the fish facility, was added as an SWP feature when it became evident that the pumps at the Banks Pumping Plant cavitated at low tide levels. CCF allows large volumes of water to enter the forebay during higher tide events so that the water elevations are higher for the pumps to draw from. Fish predation in the large CCF is believed to be significant (between 60 and 99 percent for salmon) and is in addition to the losses incurred through the collection facility process. A CCF “pre-screen loss” factor of 75 percent is used to calculate fish losses.

The JESFF was modeled after the Tracy Fish Facility (TFF), located 1 mile to the east (built in 1959). The JESFF includes some improvements, such as multiple vees for better velocity control, enlarged holding tanks, and automation; however, pre-screen losses likely overshadow the benefits of these improvements.

The fish protection and salvage facilities and operations were reviewed again as part of the CALFED process. Specifically, the IEP assembled a Fish Facilities Technical Team to investigate fish protection measures at the Banks and Tracy pumping plants in the south Delta and at the proposed Isolated Conveyance intake. The team was made up of engineers and fish biologists from state and federal agencies and outside experts. The team reviewed and guided the concept design studies performed by DWR staff. The team wrote two reports that described the projects reviewed and stated their recommendations to the IEP.

In the first report (CALFED FFTT 1996), the team looked at the fish protection at both the SWP and the Central Valley Project (CVP). The team identified general issues of fish protection such as the drawing of fish across the Delta from north to south toward the pumps and the fact that the fish were salvaged at JESFF and trucked for release at the western end of the Delta, which is not necessarily the best location for some species. The team also studied the possible fish protection measures at the Skinner Fish Facility and replacing both the JESFF and the TFF with a single facility. In addition, the team investigated replacing the two existing facilities with a single new facility at the head of CCF.

In a subsequent report (CALFED FFTT 1997), the team made recommendations for facilities and studies to address informational deficiencies for design of the fish facilities. The team preferred the Isolated Conveyance to continued water withdrawals in the south Delta, primarily because of the intensive and invasive fish collection process. If screens were to be constructed in the south Delta, the team preferred multiple-vee screens of about 2,500 cfs each and recommended that the screens be installed at the upstream side of the CCF. Predation, debris handling, and fish salvage and transport were identified as major problems that must be studied to gather data for the design of an effective fish screen in the south Delta.

The CALFED Record of Decision included a 500-cfs test facility at Tracy and a 2,500-cfs new fish facility module at Clifton Court as part of its Stage 1 actions (CBDP 2000). Because of the delay in implementing the South Delta Improvements Program, these actions have been delayed indefinitely.

At the direction of CALFED, specific studies were performed to identify improvements to the JESFF. These studies focused on the problems of capture, handling, transport, and release of fish captured at the facility (DWR 2005). Experiments were developed to address deficiencies in capture, handling, transport, and release . Some studies are complete; however, few improvements have been implemented.

15.2.3.2 Intake Description

Existing Facilities

Existing facilities at the intake to the SWP canal consist of an intake off of Old River through a gate structure and into the CCF. The CCF serves as an equalizing basin in the tidally influenced south Delta, and CCF is considered to be an area of high predation. From the CCF, water is drawn into the SWP canal and into the JESFF, which has a debris boom with a trash-collector device at its entrance. The screening structure consists of a trash rack at its upstream end followed by three and one-half vees, with louvers along the sides of the vees. Bypassed fish enter the apex of the vees and travel past the louvers and through pipes to two secondary screen facilities, one with louvers and the other with fish screens. Fish bypassing the secondary screens travel through pipes to one of seven tanks, which are installed in two buildings. The fish are lifted in buckets from the holding tanks to transport trucks, which transport the fish for release in the west end of the Delta, around Sherman Island. A good description of JESFF is provided in DWR 2005.

Proposed Facilities

The Fish Facilities Technical Team recommended a multiple-module vee-screen arrangement like that recommended for the Isolated Conveyance (CALFED FFTT 1997). The facility was recommended to be constructed at the upstream end of the CCF. A low-head pumping plant would draw water from each screen bay and fill the existing CCF. The diversion operation and capacity of the new facility were never fully resolved because drawing water into CCF during low tides could significantly impact other Delta diversions operations. Modeling studies investigating “sipping” (consistent but more constant diversion operations) versus “gulping” strategies (similar to existing operations) may require additional south Delta improvements.

A new Banks Pumping Plant intake screen would contain facilities and systems for the complex and expensive fish bypass systems, dewatering facilities, fish holding facilities, and transportation facilities. Additional debris control measures were also identified in response to the higher debris loads in the south Delta, caused mainly by invasive weed issues. New release sites would also be integral to any new fish facility at the Banks Pumping Plant.

DWR laid out several options for cost and discussion purposes. Fish agencies never adopted these plans as an approved or acceptable facility.

15.2.4 Tracy Pumping Plant Intake

15.2.4.1 Previous Studies

Numerous studies have evaluated the existing fish louvers (constructed in 1951) at the TFF and recent fish screen criteria on the intake channel for the CVP pumping plant at the head of the Delta-Mendota Canal (DMC). The intake channel conveys water from Old River to the Bill Jones Pumping Plant, where the DMC, with a capacity of 4,600 cfs, conveys both municipal and industrial water and agriculture water to Mendota Pool. The DMC is 113 miles in length and has a capacity of 3,211 cfs at the Mendota Pool. The DMC is used during off-peak and off-season times to fill San Luis Reservoir on the west side of the San Joaquin Valley (Odenweller and Brown 1982).

CDFG and U.S. Fish and Wildlife Service developed the original louvers at the TFF, at the intake to the DMC. Since that time, numerous efforts have been made to evaluate and improve the concept. These efforts all showed that louvers function effectively to screen fish that are large enough to detect and avoid the louvers and that louvers are not efficient for screening fish of less than 38 millimeters (mm) (1.5 inches) in length (Odenweller and Brown 1982).

In draft document entitled “A Proposed Technology Facility to Support Improvement and/or Replacement of Fish Salvage Facilities at Tracy and at Other Large Fish Screening Sites in the Sacramento–San Joaquin Delta, California” (Tracy Fish Facility Team 1998), various devices and methods were proposed to determine the most effective and reliable technologies for expansion to the permanent fish facility.

The list of procedures and devices being examined for use as fish screening included:

- Non-positive barriers
  - Sound
  - Electricity
  - Air bubbles
  - Light
  - Chains and cables
- Positive barriers
  - Horizontal rotary drum screens
  - Vertical drum screens
  - Filter systems
  - Horizontal traveling fish screens
  - Vertical traveling fish screens
  - Fixed screens
  - Plate along one bank
  - Sawtooth
  - Inclined

Some of the areas that caused concern with most of these devices included debris and how it affected the operation of the screen structure. The technology development structure included various options for cleaning trash racks, louvers (perhaps bar-racks) and positive barrier fish screens. Various ways of operating fish bypasses, fish lifts, holding tanks (including dewatering screens and fish sorters) and fish transporters (including release systems) were included in the technology development structure that was proposed but never constructed. The overall goal was to protect fish in the Delta and maintain a reliable water delivery system.

15.2.4.2 Intake Description

Existing Tracy Fish Facility

The CVP facilities were constructed in the early 1950s. The pumping plant, intake channel, and pilot fish screening structure (site of present TFF) were completed in 1951. Concerns regarding losses of juvenile striped bass and juvenile chinook salmon in the exported flows stimulated several years of testing of various types of fish-screening devices. By 1955, a system of louvers, bypasses, and holding tanks had been selected, and the current fish collection facility began operating in 1957 (Tracy Fish Facility Team 1998).

The existing TFF consists of two louver systems in series that divert fish from the canal, concentrating them into holding tanks. The primary louvers have a 1-inch opening and the structure is 320 feet long, 25 feet high, and angled at 15 degrees across an 84-foot-wide channel. The trash rack structure has openings of 2¼ inches. The trash rack and louvers are cleaned as necessary. The channel velocity (channel between the trash rack and the angled louvers) into the primary louvers ranges from 0.4 to 4.0 feet/second, depending on the quantity of water being diverted. The primary louver array has four 6-inch bypasses spaced 75 feet apart. The secondary channel has two rows of louvers in tandem that guide fish into a single bypass from which they are conveyed to the holding tanks. Fish from the holding tanks are transferred to trucks and moved to release sites in the Delta (Tracy Fish Facility Team 1998).

The louvers create a disturbance in flow that causes fish to turn away and eventually be carried into a nearby bypass. The probability that a fish will be louvered or guided into a bypass is strongly influenced by its swimming ability and size, the approach and bypass velocities, the debris load on the louvers and trash rack, predator abundance, and time of day.

Proposed Replacement for Tracy Fish Facility

The fish screen being proposed by the technology development group for the TFF consists of a trash boom for collecting surface trash and an open field nearby for depositing collected trash, a trash rack with a trash removal system, an open channel with fish crowders to force moving fish through the system, an angled system of louvers with bypasses and a fish screen behind to keep out smaller species of fish, fish-friendly pumps to lift the bypass flows, holding tanks for temporary collection, trucks to safely move the fish, and release sites. The facilities provide options for the fish-screening process, and some of the equipment may not be useful or improve the process. The facilities proposed offer enough variations to fully evaluate the equipment and procedures for future fish-screening sites. The issues include trying to reduce the transport of predatory species along with smaller fish. Many other areas are to be evaluated also.

Elimination, reduction, or removal of debris is a significant concern of facility operation. New facilities will be challenged more than the existing facilities, because the screen openings will be reduced from 1 inch to 0.068 inch if the new-criteria screens are installed. If the debris is not effectively removed from the screens or trash racks, it must be removed in the fish holding facilities in highly concentrated volumes. A new facility will also be challenged with difficult hydraulics due to the tidal influences and shallow water depths. The proposed Tracy Fish Test Facility will evaluate the feasibility of these systems.

15.2.5 Fish Screens for Irrigation Pumping

15.2.5.1 Previous Studies

The Delta comprises about 500,000 acres of irrigated farmland, much of which is below sea level. Hundreds of miles of waterways surround these sunken island areas, which are protected from flooding by over 1,000 miles of levees. Although the rich peat soils produce abundant crops, the continuing loss of peat soils due to oxidation, wind erosion, and compaction is responsible for continued settlement on each island; at present, some islands are as much as 25 feet below sea level.

Due to the flat and sinking topography of the Delta islands, irrigation is typically accomplished by diverting water from distributed intakes around each island's perimeter. Because of the subsided farmlands and the remote location of these diversions, siphon intakes are the prevalent intake type in the Delta. In the upland areas of the southern, northern, and eastern Delta, centrifugal and turbine pumps may be used for irrigation. With few exceptions, most diversions are privately owned riparian diversions that irrigate only a small portion of an island's total area.

Farm runoff and high groundwater on each island are captured in a central drain system, generally installed at the center of each island. Large pumps remove the excess water over the levees and to the surrounding waterway.

In the mid-1990s, CDFG inventoried, mapped, and gathered diversion attribute information on over 2,200 diversions in the Delta. Of the 2,200 Delta diversions inventoried, less than 1 percent are currently screened. Estimates of a typical diversion flow rate range from 10 to 15 cfs. Diversions occur seasonally, with the majority occurring during spring and summer, when irrigation demands are highest. The combined peak rate for all Delta diversions is over 5,000 cfs.

The fish loss impacts of Delta diversions may be a substantial source of mortality for the early life stages of some Delta fish species as well as for some fish that migrate or rear in the Delta for a portion of their life. In 1992, DWR implemented a 3-year Delta Agricultural Diversion Evaluation Program to develop reliable data about entrainment of various fish species, determine the effects of entrainment on the life stages of the species, describe the species' susceptibility to agricultural diversions during the irrigation season, and compare the data obtained from the program with information about abundance and life stages of the same species living in adjacent channels. The effort also tested the effectiveness of an experimental fish screen installed on a McDonald Island siphon intake. The screen was effective in reducing entrainment of larvae of 4 to 5 mm and larger.

In the late 1990s, DWR conducted a similar study at a large Sherman Island siphon diversion (30 cfs). Two of three side-by-side pipes were protected with screens, and one pipe was left open. Comparisons were made between the screened and unscreened diversions and what was in the adjacent waterway. Although little correlation existed between the fish composition in the waterway and the diversion, the screen did effectively keep small fish from being entrained.

15.2.5.2 Intake Description

Issues

Screening Delta diversions poses many logistical and technical challenges due to the large number of relatively small diversions. Although feasible screening options are available, they are not necessarily applicable to all sites.

Challenges include the following:

- Diversions are spread over a 700,000-acre area.
- Many sites have limited access (many on private roads).
- Levee crowns usually have only limited room on which to place facilities.
- It is not always practical to disturb levees for new facilities .
- No power is available at many diversion sites.
- Remote locations are subject to vandalism.
- Compliance enforcement is difficult.
- Tide effects and water level fluctuation must be considered.
- Brackish water and corrosion are issues.
- Invasive weeds and plugging debris must be considered.
- Invasive invertebrates (e.g., mitten crabs, quagga mussels) may be present.
- Barnacles, freshwater sponges, algae, etc., may cause biofouling.
- High winds may be present.
- Poor soils may be present.
- Water depths may be limited.
- Bed loads move and silt accumulates.
- Recreational interference may occur in waterways.
- Navigational hazards are present.
- Existing infrastructure is poor.
- Diversions are characterized by multiple individual owners.
- Capital costs must be considered.
- Operation and maintenance costs must also be considered.
- Subsidence should be considered.
- Delta smelt protection requires a large screen area.

General Screening Options

If individual diversions are screened, "end-of-pipe" screening options may be the most simple and feasible alternative if internal conveyance is not part of the project. This alternative would require that the screening media of the required surface area be attached to the suction end of each diversion pipe or pump intake.

Fish agency screening criteria require 5 square feet of screen surface area for every 1 cfs of flow. Therefore, a typical 10 cfs diversion would require 50 square feet of screen area, if designed with an integrated self-cleaning system. If the screens do not meet the agencies' cleaning criteria, eight times this surface area must be provided, or 400 square feet in this example. For practical reasons, self-cleaning systems are necessary on all but the smallest of diversions.

Screen Shapes and Sizes

To provide the necessary surface area, screen media can be wrapped in various shapes, the most common of which are cylinders, cones, and box structures. Each of these screens must be attached to the suction intake through a flanged or welded connection.

As an example, a typical 10 cfs diversion screen would require a minimum 36-inch-diameter cylinder 36 inches long or some equivalent form. The weight and drag of the screen unit will also likely require additional support since most intake pipes are currently unsupported and rest on the channel banks. Piles could be used as supports and they would be part of the fish screen structure.

Material Options

Screens have been made with various perforated plates, woven mesh, expanded metals, geofabrics, slotted plastics, and wedgewire (V wire). Material choices are limited to non-corrosive materials such as stainless steel. Wedgewire screens are the preferred medium because they are resistant to collapse, abrasion resistant, and generally the easiest to clean due to their bar shape. Copper-nickel alloy screens are also gaining acceptance to reduce biofouling; however, they are about twice as expensive and about half the strength of stainless steel for the same size section.

Cleaning Options

Cleaning systems may consist of brushes, water backwash, or air burst. Brushes are the most effective cleaning system because they provide positive cleaning action. Several Delta diversion screens that use this method effectively are currently in use. Larger Delta pump stations, such as the Contra Costa Water District's Old River Intake, also use brushes effectively.

Water backwash systems are used on several DWR-maintained screen sites on Sherman Island in the Delta, with poor results. Bearing failures and poor cleaning effectiveness have required DWR to invest in significant maintenance, modifications, and diving inspections (Whitlock, pers. comm., 2007). Air-burst cleaning methods have been used on a Suisun Marsh diversion, but this method also requires frequent inspection and cleaning by divers. The burst of air can be disruptive to each area and requires special marking in the area for safety. The problem with water and air cleaning is that neither method is very effective at removing attached biofouling, which is prevalent in the Delta. However, in other regions the use of copper-nickel alloys and anti-fouling paints has been shown to be effective in combination with these cleaning methods (McMillian, pers. comm., 2007).

Power Considerations and Options

Power considerations are essential to screen operations unless the screens are significantly oversized and thus more expensive per CDFG criteria. If power is available at a site, additional screen-cleaning options are available. However, about 45 percent of siphon diversions are not powered. Power options include solar power, as used on several cone screen installations in Suisun Marsh, and a portable generator (for limited use).

Intake Screens, Inc., recently installed two propeller-driven screens that drive a hydraulic gear–driven brush cleaner. These were installed on siphon pipes (end of pipe connection) on Ryer Island and Empire Tract, with good success.

Retrieval Options

Screen inspection and access to the screen unit is critical for maintenance, routine cleaning, and diversion reliability. The ability to easily remove the screens from the water is desirable, especially if the diversion is only used seasonally. It may also be necessary to remove screens from the water during flood events or when levee maintenance could damage the screen.

Options for retrieval in use in the Delta include track systems, hinged pipes, and lifting lugs on screens (to assist in crane removal of screens from a recessed base). Track systems, as used on the Reclamation District 999 diversion, allow the screen to be guided down a track and to fit over a docking inlet at the pipe intake. Hinged pipes, as used on the Sherman Island and Ryer Island screens, allow the screen to be raised above the water surface (via winch) for inspection from a boat. The McDonald Island test screen also uses a hinged pipe to enable biological testing with the screen on or off. Lifting lugs are used on many Suisun Marsh cone screens to seasonally remove the screens from the water during non-diversion periods. These screens are placed on an adjacent pad and pressure-washed seasonally.

Consolidating Intake Options

Consolidating diversions is one option to reduce the number of sites to be screened; however, the internal island conveyance for consolidation may not be possible for reasons of right-of-way, topography, or landowner coordination. One exception is Reclamation District 999, which diverts in the north Delta from the Sacramento River near Clarksburg. Their diversion, which is rated at a peak flow of 100 cfs, irrigates over 1,000 acres and was screened in 2006. To date, the consolidated diversion has been easy to access and maintain by the district.

Other Screening Technologies

Many experimental screening technologies are available (e.g., sound frequencies, air bubbles, fabric screens), but these technologies are not considered feasible options because fishery agencies have not approved them for fish protection.

15.3 COST ESTIMATE

15.3.1 Isolated Conveyance Intake

To date, intakes and fish screens for the Isolated Conveyance have been estimated only at the conceptual level. The cost of fish-screening facilities has been estimated on a cost per cfs basis. However, the size and cost of the facilities are more nearly proportional to the area of fish screen material. About 6 years ago, the approach velocity to the fish screens was set at 0.33 fps for salmonids. However, with the listing of the Delta smelt as endangered, the approach velocity criterion has been set at 0.2 fps for fish screens in the Delta. For a given flow, this increases the required fish screen area by 65 percent.

According to the CALFED Storage and Conveyance Refinement Team (CALFED SCRT 1997), the cost of the fish screen structure was $10,000 per cfs in October 1996 dollars. A later addition to the study set the cost at $13,000 per cfs in October 2005 dollars. Although little documentation is provided on the design criteria used, it is unlikely that Delta smelt protection was considered. Therefore, increasing these figures by 65 percent to account for the 0.2 fps approach velocity criterion and by 6 percent for escalation to August 2007 (using the Engineering News Record construction cost indices), the screen cost per cfs is about $22,700.

In a recent value engineering study for a through-Delta conveyance (DWR 2007b), the fish screens and intake structure for a 15,000-cfs Isolated Conveyance were estimated to be $273.8 million or about $18,300 per cfs. The same study suggested the unit cost of a 4,000-cfs screen on the Sacramento River would be about $31,000 per cfs. Similarly, the estimated cost of the intake and screen recommended by the value engineering team for a 4,000-cfs through-Delta facility was $113 million or $28,300 per cfs. Interpolating between the 4,000-cfs screen cost recommended by the value engineering team and the 15,000-cfs screen cost recommended by DWR, the consulting team derived the following costs for the Isolated Conveyance screens:

Screen and Intake Costs
Isolated Conveyance

	Cost per cfs	Total Cost
5,000 cfs	$27,400	$137.0 million
10,000 cfs	$22,900	$228.5 million
15,000 cfs	$18,300	$273.8 million

The unit costs in this list are consistent with the unit cost of $22,700 per cfs developed by the CALFED Storage and Conveyance Refinement Team after correction for the lower approach velocity and escalation to 2007 dollars (CALFED SCRT 1997).

The above costs do not include the main pump station or diversion facility or any construction downstream of the fish screen structure. The costs also assume that the fish bypass is relatively short and that fish are discharged close to the point of their diversion from the river.

15.3.2 Banks Pumping Plant Intake

DWR has estimated the cost of a new fish facility at the head of CCF as over $1 billion (unpublished data). Considering that the intake could be oversized for its operational issues, the unit cost of the facility would be between $50,000 and $90,000 per cfs. It should be noted that the appropriate facilities have yet to be determined. The high unit cost is due to the elaborate fish collection system and the high construction cost of large facilities and related infrastructure on relatively weak foundations in the south Delta.

15.3.3 Tracy Pumping Plant Intake

The primary source of the cost estimate for screening the DMC was taken from the TFF document of November 1998 (Tracy Fish Facility Team 1998). The cost of the fish screen facility proposed was $89 million (1998 costs) for a 2,500-cfs facility. That fish screen facility would have to be doubled for the entire diversion flow capacity. The $89 million cost estimate was developed by using detailed civil and mechanical cost estimates, with electrical costs estimated at 20 percent of the civil and mechanical costs. No engineering design or construction management costs were included in the base estimate, but a contingency of 25 percent and unlisted items of 15 percent were added. To arrive at a price for construction at 2007 price levels (using the Engineering News Record construction cost indices: 1.336 times November 1998) the facility cost estimate was used as a basis, the capacity was doubled, and engineering and construction management were added. The estimated cost of construction in 2007 is $290 million, or $58,000 per cfs.

Because appropriate facilities and operations have yet to be determined, these cost estimates should be considered preliminary and subject to change as a result of future studies.

15.3.4 Fish Screens for Irrigation Pumping

15.3.4.1 Previous and Updated Cost Estimates

The cost to screen the existing Delta diversions depends on many factors, as noted above. Site modifications or improvements are often necessary to support the intake screening facility and should therefore be part of the screen cost considerations. Improvements can include:

- Replacing existing diversion pipe and improving the existing facilities
- Pile driving for facility protection (beyond what is needed for structural reasons)
- Bank protection due to new facilities
- Construction mitigation
- Improved access to the site
- Flow control facilities to limit peak flows for screen sizing
- Remote monitoring of facilities
- Power connection, as necessary

Previous estimates of screening Delta diversions have incorrectly used cost data from other screen sites. For example, cost information from screen programs, such as those in Oregon and

Washington, include screens built at diversion dams with stable water levels and easy access to facilities. Also, the screens in these examples are designed to higher velocity criteria than the criteria applicable to the Delta due to the velocity criteria established for the Delta smelt. Establishing the applicable design criteria and program objectives is critical to developing good cost data. Fortunately, several screen sites that meet conservative objectives and are applicable to estimating diversion screen costs have been developed (though they do not include the site improvements as described above)

Unpublished reports by the CDFG in the late 1990s estimated the cost of Delta screen installations at individual diversions to be between $3,000 and $5,000 per cfs (where average maximum flow for Delta diversions is about 10 to 15 cfs). These reports estimated the cost of screening the multitude of Delta diversions at more than $100 million, not including operation and maintenance costs. Given the potential 65 percent increase in screen size necessary to meet the Delta smelt protection criteria, these estimates would rise to $165 million.

Recent screen installations on Delta siphons show that costs are more likely between $5,000 and $10,000 per cfs (Hayes, ISI 2007), not counting ancillary improvements. Higher unit costs are generally associated with the smaller diversions.

For purposes of estimating costs, it is assumed that the average peak diversion of all the 2,200 screen sites is 10 cfs. Using a unit cost of $7,500 per cfs, or $75,000 per diversion, costs for screen facilities alone could be $165 million. Additional costs for related site improvements could double this cost to $330 million.

15.4 RISK REDUCTION ESTIMATE

This section describes the risk reduction opportunity for the intake and screens component of each facility.

15.4.1 Isolated Conveyance Intake

The intake and fish screens may affect the capability of Isolated Conveyance to perform the functions for which it was designed. The intake and fish screens for the Isolated Conveyance could affect the functions of the conveyance in two areas:

1. The screens could clog with debris or sediment, thereby restricting delivery of water into the conveyance. The screens, a trash boom, a trash rack, and fish screen cleaners would have mitigating effects by blocking debris from impinging on the screens, keeping the screens open for water delivery to the canal.
2. When the Isolated Conveyance is in operation, the fish screens would serve to prevent the entrainment and loss of fish in the Isolated Conveyance. The fish taken into the intake would be returned to the river at a point close to where they were diverted. The main risk is that the screens may not function to improve fish survival significantly. Additional fish predation or other factors due to the facility could influence overall fish survival rates due to the facilities.

15.4.2 Banks Pumping Plant Intake

Constructing and operating a new fish screen in the south Delta could reduce the risk of diversion shutdowns and improve Delta fish protection. However, the overall benefit of such an action is unclear. The impacts of the fish collection, transportation, and release facilities are a critical and uncertain element of the process for many Delta species. These actions are necessary because the pumps are situated in a dead-end area of the Delta, with poor circulation. If fish move with the flows, they must be collected and moved away from the pumping influences to improve their chances of survival.

The risks associated with continued operation in the south Delta (risks due to reliance on the Delta's levee integrity and water quality) are also risks related to the successful operation of a fish facility. If, for instance, water quality becomes too saline for delivery due to levee failures and island flooding, the pumping facilities would be shut down. Under this condition, a new fish facility would not offer any benefit. Similarly, if larval-sized fish are present in the south Delta and they require protection, the fish facilities are unlikely to benefit those fish. Pumping shutdowns could result while the fish are in the vicinity. The poor circulation in the area may not be enough to move fish from the area.

15.4.3 Tracy Pumping Plant Intake

The risks involved with operating a new fish facility at the Tracy Pumping Plant are similar to those at the Banks Pumping Plant. The entire process needs to be taken into consideration in evaluating risks and costs. In addition to the significant capital improvements required under this building block, the high costs of ongoing operation and maintenance must be considered. New facilities are unlikely to prevent the shutdown or curtailment of the pumping facilities when endangered species are encountered, as in the past. Although new screening efficiencies would likely be improved significantly under this building block, all new facilities would still have some fish loss associated with their operation.

Some of the major increased risks of operating fish screens in the south Delta are complicated fish collection systems for multiple fish species and sizes, high debris loads due to invasive weeds, tidal actions and difficult hydraulics, shallow depths, high winds, poor structure foundations, remote facilities, and constantly changing water depths. The existing fish protection screens at the site are inadequate and can be improved. Working examples of the technologies discussed in this building block can be applied at this site and could reduce risks of water supply interruption, if operated appropriately.

15.4.4 Fish Screens for Irrigation Pumping

The risks associated with the irrigation intakes in the Delta are that the agricultural producers will not receive the required water to meet their needs and that the screens will not adequately protect the aquatic resources for smaller fish species (less than 20 mm) that may be present near the diversions. The issues associated with these risks are summarized below.

Risks to Water Delivery

- The high amounts of debris in the water could block screens and prevent delivery of water.
- The useful life of the screens could be limited if they are not maintained; the cost of maintaining these small screens could be significant.

- Poor screen design or maintenance practices could prevent the diversions from operating efficiently.

Risks to Aquatic Resource Protection

- Many diverters are unlikely to maintain screens without a coordinated and centralized support system.
- Poor screen design or maintenance practices could prevent the diversions from operating efficiently.
- Protection of larval fish may not occur, because the screens are not designed for egg and larval stage protection.

The loss of fish resources due to multiple, small, unscreened diversions is not well understood. Existing diversions are more likely to entrain fish that reside near the levee shorelines and at deeper water depths. Pelagic fish that reside in the center of the channels may not benefit as greatly as other fish with the addition of new screening facilities.

15.5 FINDINGS AND CONCLUSIONS

15.5.1 Findings

After reviewing relevant reports and data, considering our personal experience with fish screening in the Delta, and applying our professional judgment , the consulting team has the following findings.

1. Fish-screening technology is available and has been successfully tested for fish of about 25 to 30 mm in length and larger.
2. No effective, proven means are available to physically screen eggs and larval life stages of fish from intakes.
3. Screens operating in the Delta that meet the current criteria for Delta smelt have been effective at excluding larval life stages (fish smaller than 25 mm in length) from small intakes. However, at the large Tracy and Banks Pumping Plant intakes, the fish survival benefits of collecting, transporting, and releasing these small fish is uncertain.
4. The intakes at the Isolated Conveyance, Tracy Pumping Plant, and the Banks Pumping Plant require large facilities to screen flows from 4,000 cfs to 15,000 cfs. These large flows can be successfully screened using multiple in-canal vee-type screens of about 2,500 cfs capacity in each module. These types of screens at this size have proved successful at other installations.
5. The possible biological benefits of screening smaller, local intakes in the Delta are not clearly known, because many other factors can influence the overall degree of benefit. Reducing direct fish losses could be significant, because fish entrainment and impingement losses at the screens would approach zero for fish over 20 mm. One study of fish entrainment at existing intakes demonstrated these results by comparing side-by-side screened and unscreened diversions. However, more work is needed in this area.

6. For several reasons, the south Delta fish screens will not be as effective at protecting fish as those in the north Delta or at an Isolated Conveyance Facility intake. First, the greater amount of debris in the south Delta will have to be removed by mechanical means, which will affect fish survival. Second, the fish bypassed in the screening facility must be transported to another location in the Delta. This process increases the stress and mortality of the fish. Third, the south Delta is more likely to entrain smaller fish that cannot be effectively screened. Fourth, the poor water circulation in the south Delta makes the intake more vulnerable to extended outages due to fish being trapped in a dead-end area.
7. If fish protection is the only consideration at diversions, the CALFED Fish Facility Technical Team recommended screening an Isolated Facility diversion. However, other issues must be considered in selecting a preferred alternative, such as water quality in the Delta and the quality of diverted water and water supply.
8. The south Delta screening facility will cost more than similarly sized facilities in the north Delta for at least four reasons. First, poor foundation conditions will require expensive foundations. Second, additional structure and mechanical devices are required to remove the additional debris in the water. Third, the bypassed fish require holding facilities and a means is needed to transfer fish to release sites throughout the Delta. Fourth, the tidal influences and shallow water depths could require a larger facility than required in the north Delta.

15.5.2 Conclusion and Recommendations

15.5.2.1 Conclusion

The Delta is a complex and unique environment with multiple competing interests and resources. These relationships and balances have been studied for some time, but it is still unclear what the benefits and constraints are for many proposed actions. Despite this uncertainty, fish screening does reduce some risk of fish loss for a given diversion and is therefore likely to be a part of any future Delta action. Also, state and federal regulatory agencies require that diversion impacts be mitigated with appropriate fish protection technologies, such as fish screens. Endangered species protections require these measures as reasonable and prudent because they can reduce fish losses, if designed appropriately.

In addition to fish screening actions, a new facility must also consider its operational influences on diverted water quality, water quality in the Delta, water supply to Delta agriculture, impacts on competing fish and invertebrate fish populations, and other factors. These issues influence the choice of fish-screening locations, size, design, and operation. To date no clear option has been identified as being the most advantageous given all the issues involved. The choices range from a full Isolated Conveyance Facility to screening the existing intakes in the south Delta. Combinations of these alternatives have also been proposed, including the Dual Conveyance Facility recommended by CALFED in its Programmatic Environmental Impact Report. Although a Dual Conveyance Facility may lead to more flexible operations, the complexity of operation would be a challenge and would come at significant additional cost due to duplicative facilities for similar functions. Considerable work on and discussion of these alternatives remains before they can serve as a guide to significant Delta improvements.

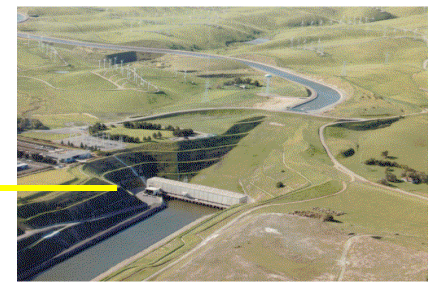
The implementation of effective fish screens using state-of-the-art techniques is feasible and can be effective at reducing direct fish losses at diversions. Screening large and small diversions has advanced to the point that the technologies are available and are ready for application at an Isolated Conveyance or a small Delta diversion with little additional study. The same technology could be applied to the Banks and Tracy Pumping Plant intakes in the south Delta; however, the problem of additional debris, fish collection, handling, transport, and release requires careful consideration and additional study.

15.5.2.2 Recommendation

The CALFED program and earlier programs have already undertaken much work . It is recommended that this body of knowledge be used as the basis for selecting the location or locations for the intake and associated fish-screening facilities.

Figures

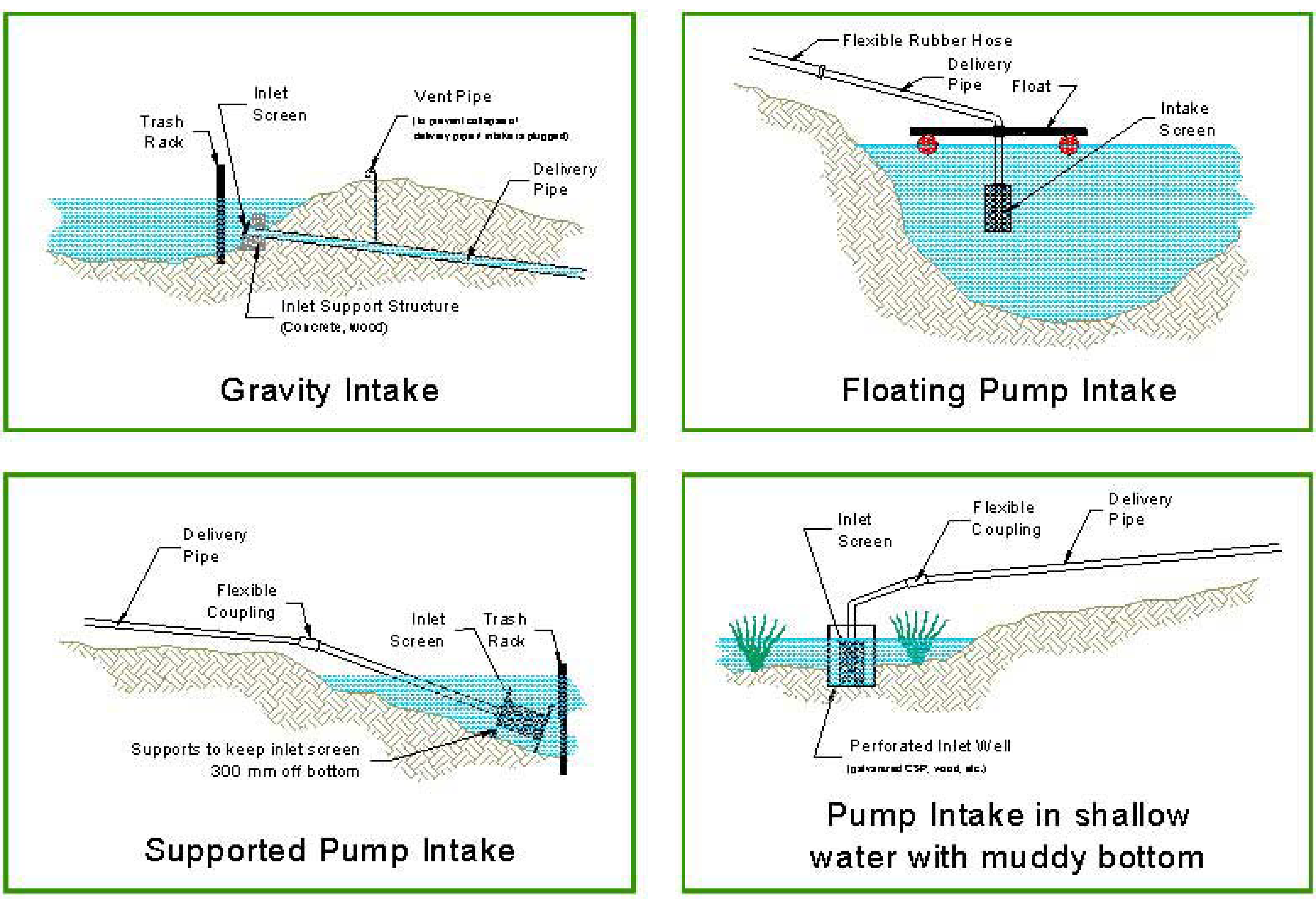
For these two facilities, fish would be collected and transported in tank trucks to other Delta locations.



Harvey O. Banks Pumping Plant

Tracy Pumping Plant

Fish Screen Locations on SWP and CVP Pumping Plants



Credit: Figures provided by Agri-Food Canada

Fish Screen Applications for Local Agricultural Withdrawls (must include acceptable cleaning)

Project Costs

South Delta Fish Screens

Location	Capacity (cfs)	Cost
Banks Pump Station	10,670	$619 M
Tracy Pump Station	4,600	$290 M

AGRICULTURAL DIVERSIONS
Currently 2,200 agricultural diversions (1% screened)
Average diversion rate ≈ 10 cfs
Unit cost of $7,500/cfs = $75,000 per diversion
Costs for screen facilities ≈ $165 million

Sacramento River Fish Screens

Location	Capacity (cfs)	Cost
Delta Cross Channel	3,500	$137 M
Isolated Conveyance Facility	15,000	$274 M
Armored Pathway	15,000	$274 M